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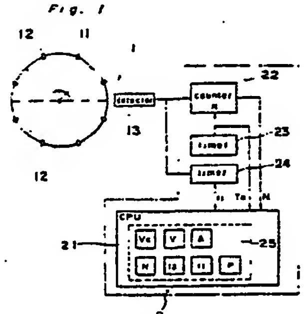
(54) Method of and apparatus for measuring revolution speed.

(57) In a measuring method of revolution speed, a calculating operation is made at a fixed time period, using the number of pulses detected in a fixed time period and the lapse time between the leading pulses or the final pulses of current period and previous period.

The method of calculation of the present invention is applied when no pulses have been detected during an operation period, and, also, when a pulse is detected after a period or a number of periods of no pulse detection, thereby to obtain a smoother and more accurate estimation during these occasions where sufficient information is lacking to determine definite values.

An apparatus for carrying out the above method includes: pulse generating means (13,22,23) for generating pulses at a rate in inverse proportion to the revolving speed of a rotating member and operation means (21) for carrying out the calculation method steps mentioned above.

Fig. 1



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Method of and Apparatus for Measuring Revolution Speed

BACKGROUND OF THE INVENTION

The present invention relates to a method of and an apparatus for measuring revolution speed, which is adapted to generate pulse signals at an interval in inverse proportion to the revolution speed of a rotary member and to calculate the revolution speed of the rotary member from the spacing of the pulse signals thus generated.

Although it has been known to calculate the revolution speed of the rotary member either from the number of the pulses within a unit time, or from the pulse spacing, errors of the calculation for the revolution speed of the rotary member become larger at either low speed or high speed in each case. Therefore, a method is known of using the number of the pulses N within a unit operation period TM, and a lapse time T between the lead pulse of a unit operation period and the lead pulse of the previous unit operation period or between the pair of final pulses, the revolution speed V being given as follows.

$V = 2\pi RN/ZT = \alpha N/T$

wherein the radius of the rotary member is R, the number of pulses generated per revolution is Z.

Fig. 4 is a chart showing a relationship among a unit operation period TM, a lapse time T, and a number of pulses N. As a varying lapse time T like T1 through T4 is used in accordance with the pulse detection timing, instead of the fixed operation period TM, this method improves the operational accuracy. However, when the revolution speed becomes extremely low, the number N of the pulses to be fed into the unit operation period TM becomes zero (N = 0) and under such a condition it becomes impossible to carry out the subsequent operation.

In order to remove such an inconvenience, there is proposed a system of obtaining the estimated value of the revolution speed for such a unit operation period as N = 0, so that the operation of the system may be effected without hindrance (for example, see Japanese Laid-open Patent Application Tokkaisho No. 62-241755). The above proposal is to estimate the speed for N = 0 period from the revolution speed and the acceleration obtained for the previous period. A measured speed is obtained when a pulse has been detected in the next period, while an acceleration for this period is estimated from the estimated speed for previous period and the measured speed for this period. Also, when the acceleration for the previous period is positive, it is assumed to be zero (0) at the estimation of the speed for N = 0 period.

In the system disclosed above, the estimated value of the speed for N = 0 period is obtained by the use of the speed estimated during the previous period. When at least two of the N = 0 periods continue, the estimation errors are added one after another, so that it is ample is possibility that the operation results become considerably out of the actual speed. Also, the speed curve connecting the measured speed with the estimated speed may lack its smoothness. Especially, the acceleration, a differentiated value of speed, becomes extremely erroneous. Furthermore, it cannot be applied for the acceleration phase as it is aimed only for the deceleration phase.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a method of and an apparatus for measuring revolution speed, wherein the accuracy of the estimation of the speed for a unit operation period when pulses have not been detected is higher and the speed curve obtained is smoother. It may also be applicable to both of the deceleration and the acceleration phases.

For the solution of these problems, first and second inventions are to obtain the revolution speed for the unit operation period in which the pulse signals have not been detected within a fixed unit operation period TM, by comparing and selecting the smaller value of two estimated values, where one estimated value of the revolution speed for the current unit operation period is obtained from the revolution speed and the deceleration calculated for the previous unit operation period, and another estimated value of the revolution speed is obtained by assuming that the number of pulses N is 1 and the lapse time T is the time from the detection time of the last pulse signal to the completion time of the current unit operation period.

According to third and fourth inventions, in a case where pulse signals are not detected during one unit operation period or a plurality of continuous unit operation periods, and pulse signals are detected during the next current unit operation period, the revolution speed calculated during the previous unit operation period is ignored and the revolution speed for the current unit operation period is calculated by the use of

the lapse time from the detection time of the last pulse signal to the detection time of the pulse signal during the current unit operation period, and also, the acceleration for the current unit operation period is calculated by the use of the revolution speed for the current unit operation period, the revolution speed calculated for the unit operation period in which the last pulse signal has been detected, and the lapse time between these pulses.

In the first and second inventions, the latter estimated value of the revolution speed obtained from the lapse time between the detection time of the last pulse signal and the completion time of the current unit operation period is the maximum possible revolution speed, which is obtained if a pulse is actually detected at the end of the current unit operation period. Besides, as this estimation is effected not on the basis of the result of calculation for the previous period, which is inevitably an estimated value if the period is a no-pulse period, but on the basis of the last pulse signal actually detected, the estimation errors are not added up one after another when the no-pulse period continues. Because the smaller one is selected as the revolution speed for the no-pulse period through the comparison between the maximum possible estimated value and the estimated value of the revolution speed obtained from the extension of the operation result for the previous unit operation period, a value of higher estimation precision is obtained than in the case where an estimated revolution speed obtained from the extension of the operation result for the previous unit operation period is directly assumed as the revolution speed.

Also, in a method of and an apparatus for measuring operation in the third and fourth inventions in the case where pulse signals are detected after the no-pulse period, the revolution speed and the acceleration are calculated in accordance with the last pulse signal actually detected and the pulse signal currently detected, a higher precision value closer to the actual speed is calculated as the revolution speed and the acceleration, so that the estimation errors are not added one after another even if the non-pulse period continues.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become apparent from the following description taken in conjunction with preferred embodiments thereof with reference to the accompanying drawings, throughout which like parts are designated by like reference numerals, and in which:

Fig. 1 is a schematic block diagram of an apparatus in one embodiment of the present invention;

Fig. 2 is a wave form chart for illustrating the operation;

Fig. 3 is a flow chart showing the operation procedure; and

Fig. 4 is a view for illustrating the general revolution speed measuring method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals through the accompanying drawings.

Referring now to the drawings, there is shown in Fig. 1, a schematic block diagram of an apparatus according to one preferred embodiment of the present invention, which includes a pulse generating means 1 for generating pulse signals at an interval in inverse proportion to the revolution speed of a rotary member 11, and an operation means 2 for effecting various types of operations. The pulse generating means 1 is, for example, composed of a plurality of magnets disposed at equal intervals on the outer periphery of the rotary member 11, and an electromagnetic pick up 13 disposed close to them. The operation means 2 is composed of a counter 22, a timer 23 for counter use, a reference timer 24 for time use, and so on, as well as a CPU 21 as a center, with a memory 25 for storing the various types of data being provided in a CPU 21.

Fig. 2 is a wave-form chart for illustrating the operation, which includes pulse signals 31, an actual revolution speed curve 32 of the rotary member 11, a revolution speed curve 33 obtained by the operation. In the chart, reference character N is a number of the pulses detected during an individual unit operation period TM, reference character P is a number of the continuations of no-pulse unit operation period, reference character T is a pulse interval or a lapse time, reference character t is a time, reference character to is a completion time of the individual unit operation period, reference character t1 is a final pulse detection time during current unit operation period, and reference character t2 shows a final pulse detection time during the unit operation period in which a last pulse has been detected. Also, reference characters n1,

n2, ... show the numbers of the unit operation periods for illustration use.

Fig. 2 shows an example in a case where the pulse signal 31 is detected at such timing as shown during a deceleration phase. The operation will be described hereinafter with reference to the flow chart of Fig. 3, wherein V is a revolution speed to be obtained for the current period, Vc is a revolution speed obtained for the previous period, A is an acceleration, $\alpha(=2\pi R/Z)$ is a constant to be obtained from the radius R of the rotary member 11 and the number of pulses Z during one rotation of the rotary member 11, P is a continuation number counting the successive periods in which no pulses has been detected, and PM is the maximum value allowed for P at which the estimation operation is closed assuming the rotary member 11 should be at a standstill. The value PM is set in advance, for example, as 8.

The operation is adapted to be effected at the completion time to of the respective unit operation period TM. The pulse number N during the period and the final pulse detection time t1 are read every time the respective unit operation period TM passes. When the detected number of pulses N is not equal 0, it is judged whether or not P is smaller than PM (P<PM). If P<PM, for example, as shown in the unit operation period n2, the program moves to step S1 and the speed V is calculated by the following equation.

$$V = \frac{\alpha N}{t1 - t2} \qquad (1)$$

In the case of the operation period n2, the actual pulse detection time is used for both t1 and t2, because the pulse signal is also detected during the previous operation period n1. When Vc = 0 is not satisfied, the program moves to the step S2 and the acceleration A is calculated by the following equation.

$$A = \frac{V-Vc}{(P+1)TM} \qquad \ldots\ldots (2)$$

However, if Vc = 0, A is assumed as 0. The data are renewed like t2←t1, P←0, Vc←V for the operation in the next unit operation period.

It is to be noted that the operation t2←t1 is not executed at the no-pulse operation period as described later. Therefore, if the previous period has no-pulse, the detection time of the last pulse remains at t2 and the lapse time T from the detection time of the last pulse t2 to the detection time t1 in the current operation period is used as the t1←t2 in equation (1). See operation period n4 or n6 of the illustrated example Fig. 2.

Also, when N = 0 is not satisfied, and P<PM is neither satisfied (namely, P = PM), it is assumed that a movement is just beginning after some periods of complete stop. In this case, V is assumed as 0 at the step S3 and A is also assumed as 0 at the step S4, with the data being renewed like t2←t1, P←0, Vc←0.

Then, the operation period of the no-pulse, i.e., the case of N = 0 will be described. During P<PM like, for example, n3 (also, n5, n7), and when pulses exist in the previous operation period, one estimated value of the speed is calculated in accordance with the equation of

$$V = Vc + A \cdot TM \cdot (P + 1) \qquad (3)$$

from the revolution speed Vc and the acceleration A calculated for the previous operation period. And another estimated value of the speed is calculated by the equation of

$$V = \frac{\alpha}{t0 - t2} \qquad (4)$$

as in the step S5 by the use of the lapse time T from the detection time t2 of the last pulse to the completion time t0 of the current operation period. The smaller one of the values obtained by both equations (3) and (4) is selected as the speed V of the current unit operation period. Unless Vc = 0, the program moves to the step S6 and the acceleration A is calculated in accordance with equation (2). When Vc = 0, A = 0 is applied. The data is renewed like P = P + 1. As the t1 does not exist, t2←t1 is not executed. Also, Vc←V is not executed because Vc should be a definite value when a pulse is detected.

When the previous operation period has no-pulses i.e. P ≠ 0 as in period n8 and its subsequence, the calculation is effected as in the above description. In this case, the detection time of the last pulse signal which is detected at the period before the previous period or even further before is used as the time t2.

When N = 0 is satisfied, but P<PM is not satisfied, it is assumed that rotary member 11 is at a standstill because the no-pulse periods have continued longer than PM. The estimated value of the speed, and the acceleration are made all 0, V = 0 at step S7, A = 0 at step S8, with the data being renewed like P←PM, Vc←0.

The curve 33 of Fig. 2 shows a revolution speed curve to be obtained from the operation described above, wherein the 0 mark is a calculated speed by equation (1), the Δ mark is an estimated value of the speed by equation (3), the X mark is an estimated value of the speed by equation (4). It can be seen that

the smaller value of these two estimations is always a better approximation of the actual revolution speed.

As is clear from the foregoing description, according to the embodiment of the present invention, in the first and second inventions, the revolution speed for the period when the pulse signals have not been detected is determined by selecting the smaller value of the two estimated values, one estimated value obtained from the revolution speed and the acceleration calculated for the previous unit operation period, and another estimated value obtained by the use of the lapse time from the detection time of the last pulse signal to the completion time of the current unit operation period assuming that the number of pulses is 1.

Also, in the third and fourth inventions, in the case where a pulse signal has been detected after the no-pulse period, the revolution speed and the acceleration of the current unit operation period are calculated by the use of the lapse time from the detection time of the last pulse signal to the detection time of the pulse signal of this period.

Even in any invention, estimation errors are not added one after another, even when the pulse interval becomes wider and the non-pulse period continues, so that the difference between the estimated values for non-pulse periods and the measured value for the pulsed period becomes smaller. The revolution speed curve thus obtained becomes smoother and also closer to the actual speed curve as compared with the prior art, which is applicable advantageously to various controls of the rotary member or others. It can be also applied to either the deceleration or the acceleration phases.

Although the present invention has been fully described in connection with a preferred embodiment thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

Claims

1. A method of measuring revolution speed comprising the steps of detecting pulse signals generated at an interval in inverse proportion to the revolution speed of a rotary member, calculating the revolution speed of the rotary member for each unit operation period from the number of pulses within a fixed unit operation period, the lapse time between the leading pulse of current unit operation period and the leading pulse of previous operation period or between the final pulses of each operation periods, obtaining both of a first estimated value from the revolution speed and the acceleration calculated for the previous unit operation period when no pulse signal is detected within a certain unit operation period, and of a second estimated value in the case of that the pulse number is/on the employment of the lapse time which is a time from the detection time of the last pulse signal to the completion time of the current unit operation period, and

selecting the smaller value of the above two estimated values to be designated as the revolution speed for the current unit operation period.

2. An apparatus for measuring revolution speed comprising a pulse generating means for generating pulse signals at an interval in inverse proportion to the revolution speed of a revolution member, an operation means for detecting pulse signals from the pulse generating means, calculating the revolution speed of the rotary member for each unit operation period from the pulse number within a unit operation period and the lapse time between the leading pulse of the unit operation period and that of previous unit operation period or between each final pulses thereof, obtaining one estimated value of the revolution speed for the current unit operation period from the revolution speed and the acceleration calculated for the previous unit operation period when no pulses have been detected within a certain unit operation period, obtaining another estimated value of the revolution speed on assuming that the pulse number is 1, with using the lapse time from the detection time of the last pulse signal to the completion time of the current unit operation period, and adopting the smaller one through the comparison of these two estimated values as the revolution speed for the current unit operation period.

3. A method of measuring revolution speed comprising the steps of detecting pulse signals generated at an interval in inverse proportion to the revolution speed of a rotary member, calculating the revolution speed of the rotary member for each unit operation periodfrom the number of pulses within the unit operation period, the lapse time between the leading pulse of the current unit operation period and that of the previous unit operation period or between each final pulses thereof, when pulse signals have not been detected in a previous unit operation period or a plurality of continuous unit operation periods, but the pulse signals are detected in the next current unit operation period following such no-pulse unit operation period, calculating revolution speed for the current unit operation period by the use of the lapse time from the

detection time of the last pulse signal to the detection time of the pulse signal in the current unit operation period, and calculating the acceleration for the current unit operation period by the use of the revolution speed for the current operation, the revolution speed calculated for the unit operation period in which the last pulse signal has been detected, and the lapse time between these periods.

4. An apparatus for measuring revolution speed comprising a pulse generating means for generating pulse signals at an interval in inverse proportion to the revolution speed of a rotary member, an operation means for detecting pulse signals from the pulse generating means, calculating the revolution speed of the rotary member for each unit operation period from the pulse number within the unit operation period and the lapse time between the leading pulse of current unit operation period and that of previous unit operation period or between each final pulses thereof, and ignoring the revolution speed obtained for the previous no-pulse unit operation period when pulse signals have not been detected in a unit operation period or a plurality of continuous unit operation periods, but the pulse signals have been detected in the next current unit operation period following such no-pulse unit operation periods, in the operation means, calculating the revolution speed for the current unit operation period by the use of the lapse time from the detecting time of the last pulse signal to the detection time of the pulse signal in the current unit operation period, and calculating the acceleration for the current unit operation period by the use of the revolution speed for the current unit operation period, the revolution speed calculated for the unit operation period in which the last pulse signal has been detected, and the lapse time between these periods.

Fig. 1

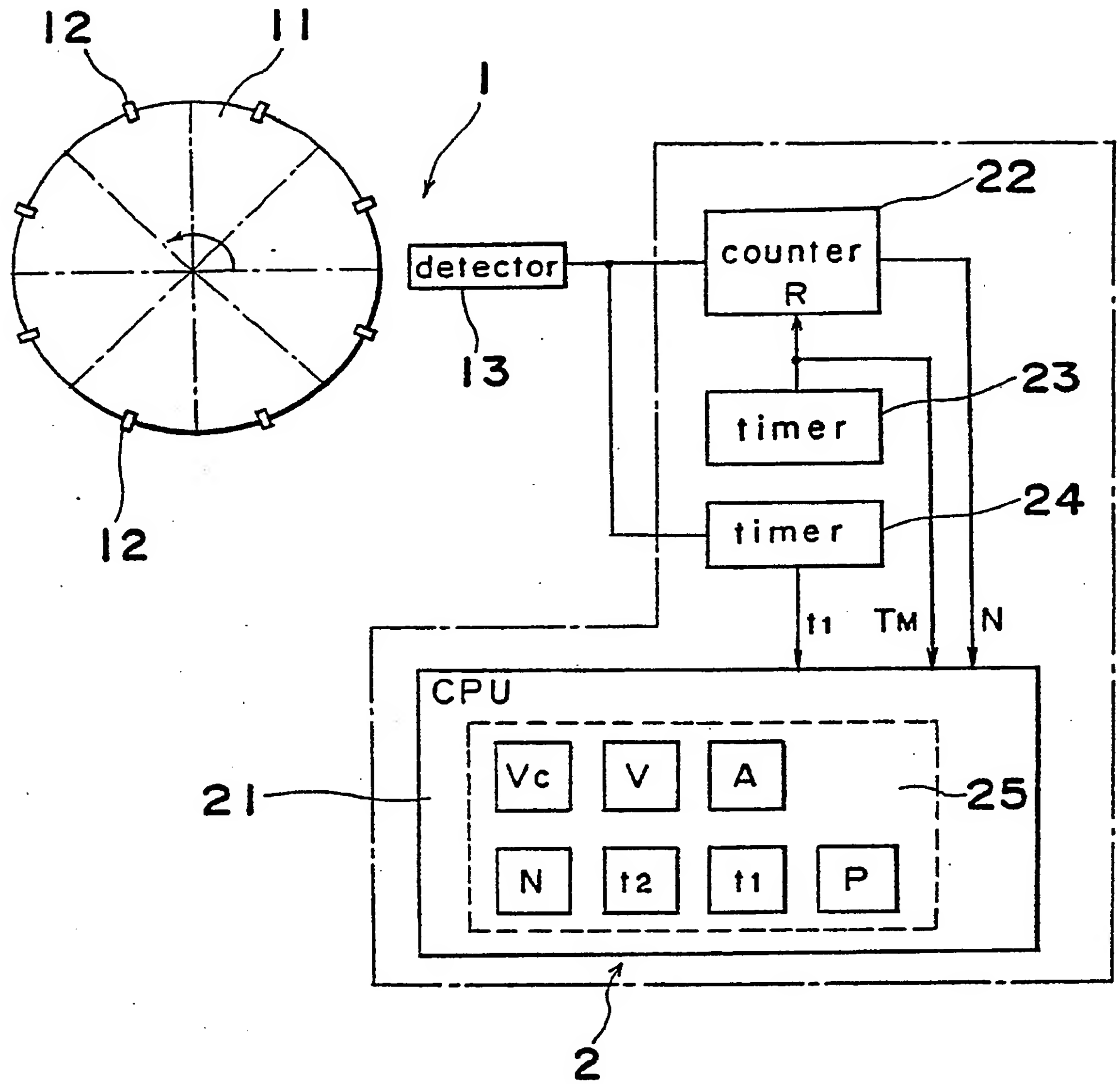

12
11
1
22
counter R
detector
13
23
timer
24
timer
12
t1
TM
N
CPU
Vc
V
A
21
25
N
t2
t1
P
2

Fig. 4

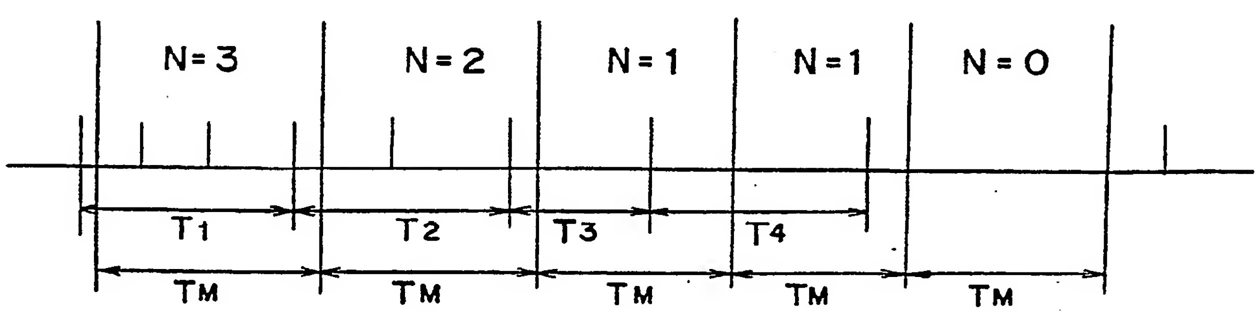

N=3
N=2
N=1
N=1
N=0
T1
T2
T3
T4
TM
TM
TM
TM
TM

Fig. 2

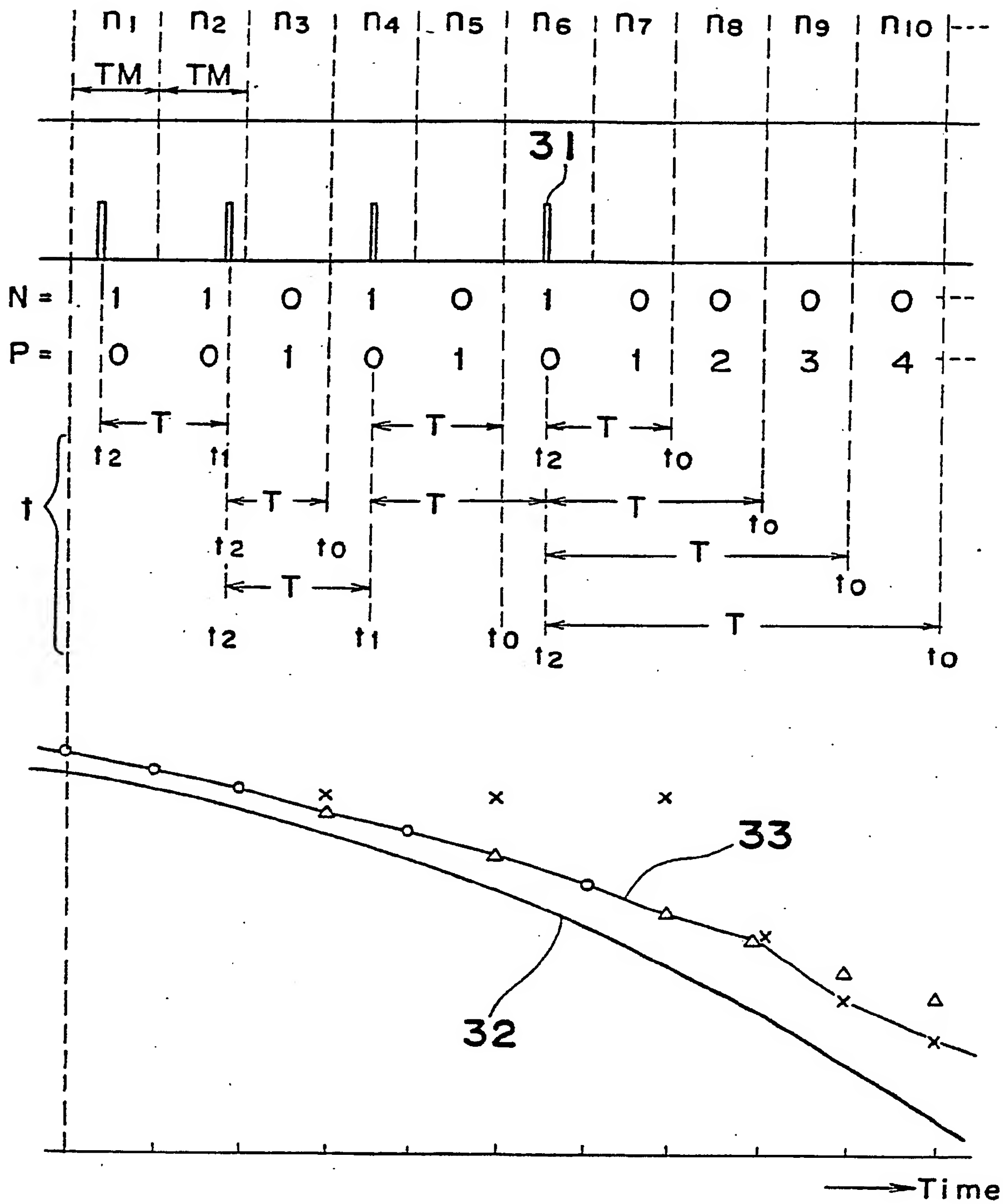
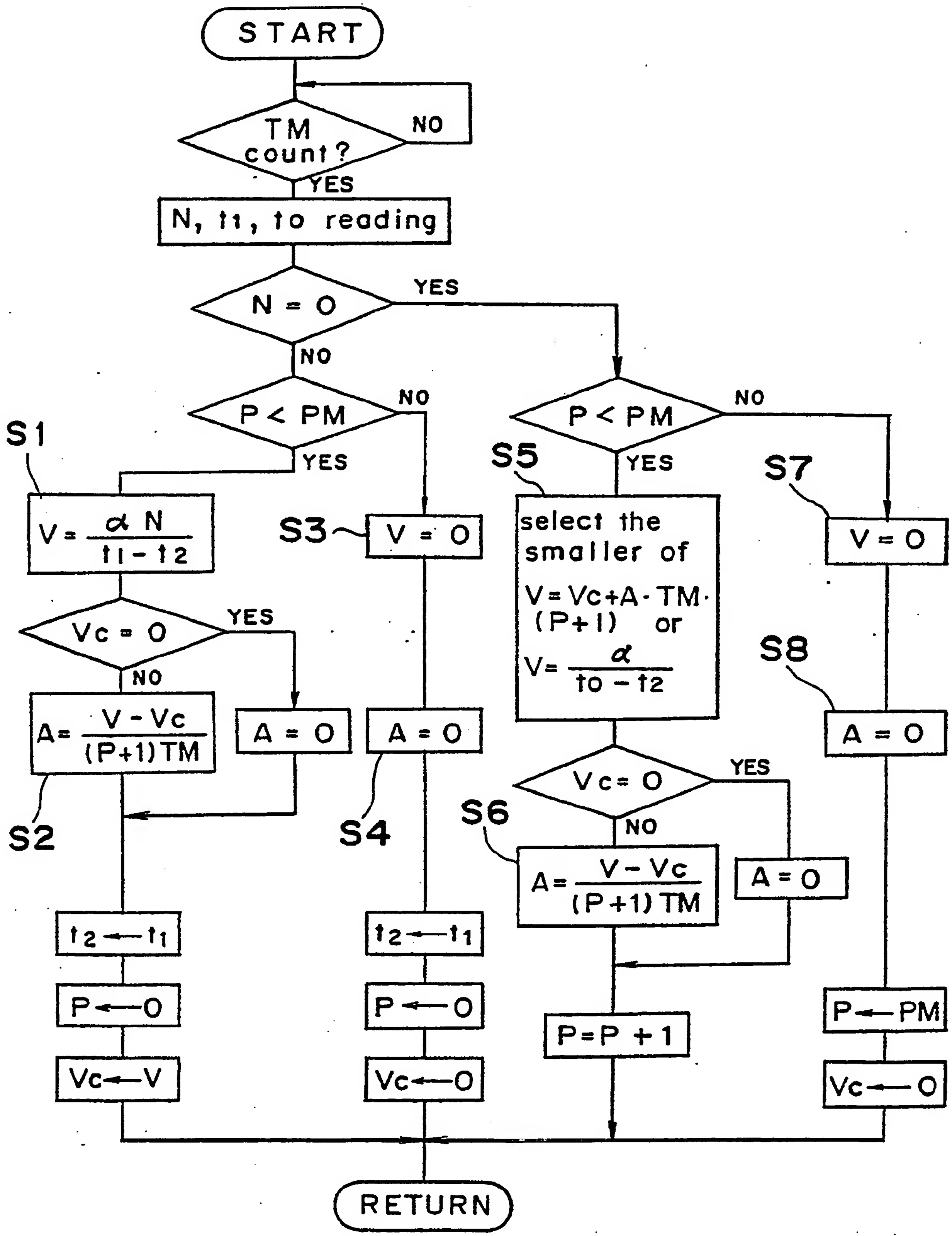

n1
n2
n3
n4
n5
n6
n7
n8
n9
n10
TM
TM
31
N = 1 1 0 1 0 1 0 0 0 0
P = 0 0 1 0 1 0 1 2 3 4
T
t2
t1
t0
t
33
32
Time

Fig. 3


START
TM count?
NO
YES
N, t1, to reading
N = O
YES
NO
P < PM
NO
YES
S1
V = α N / t1 - t2
Vc = O
YES
NO
A = V - Vc / (P+1) TM
S2
A = O
S3
V = O
A = O
S4
t2 ← t1
P ← O
Vc ← V
t2 ← t1
P ← O
Vc ← O
P < PM
NO
YES
S5
select the smaller of
V = Vc + A · TM · (P+1) or
V = α / to - t2
Vc = O
YES
NO
S6
A = V - Vc / (P+1) TM
A = O
P = P + 1
S7
V = O
S8
A = O
P ← PM
Vc ← O
RETURN

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EUROPEAN SEARCH REPORT

Application Number

EP 89 10 6713

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A,P	US-A-4 811 232 (HOASHI et al.) * Column 4, lines 38-58; figure 6 * & JP-A-62 241 755 (22-11-1987)(Cat. D)	1-4	G 01 P 3/489
A	EP-A-0 090 717 (THE BENDIX CORP.) * Page 4, lines 20-27; figure 2 *	1-4	
A	PATENT ABSTRACTS OF JAPAN, vol. 6, no. 233 (P-156)[1111], 19th November 1982; & JP-A-57 135 362 (NISSAN JIDOSHA K.K.) 20-08-1982 * Abstract *	1-4	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

G 01 P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	31-08-1989	HANSEN P.

CATEGORY OF CITED DOCUMENTS

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